SYN-TES: Human colour and light synthesis. Towards a coherent field of knowledge.

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ABSTRACT
The research project SYN-TES aims at contributing to a theoretical development transforming the field of colour and light into a coherent field of research. This includes the identification of important problems and the development of theoretical and methodological tools for the trans-disciplinary understanding necessary to solving them. Special emphasis is put on the spatial interaction of colour and light in architecture.
The work has the form of seminars /workshops where colour and light specialists from different academic disciplines (six Nordic universities) and companies (light sources, paint, colorimetric standards, window glass) examine different aspects of the problem complex. Sub-projects deal with the epistemology and concepts of colour and light, with methods for analysing colour and light in existing architectural spaces and with the relationship between energy efficiency and light quality.
Keywords: Light perception, Colour perception, Space perception, Trans-disciplinary

1. INTRODUCTION

This paper is a report from a work in progress, started in January 2010. The project addresses the lack of interdisciplinary co-ordination of knowledge in the field of colour and light. The main objective is to synthesise existing knowledge through the active participation of practitioners from leading colour and light corporations and researchers already working with colour and light from different disciplinary viewpoints. The aim is to contribute to forming a coherent field of knowledge dealing with colour and light, and their spatial interaction.

2. STARTING POINTS

Man lives in a continuously changing, three-dimensional reality. Our cognitive and perceptive systems have been formed within this context. The most important spatial sense is sight. Colour and light together construct our mental image of space.
The experiences of colour and light are interdependent and cannot be analysed separately. Colour and light in con-

structed spaces influence our experiences and feelings, our comfort and our physiological well-being.
Today's increasing demand for low energy consumption, climate consideration and sustainable development could be met by optimised co-ordination of colour and lighting design. There is an on-going large-scale changeover from traditional to new light sources. The understanding of the visual and biological effects of the new technical solutions is, however, still limited.

3. MAIN PROBLEMS

3.1 Fragmented knowledge and unclear concepts

A deep understanding of the interaction between colour and light demands an interdisciplinary approach, including such fields as psychology, neurology and lighting technology, as well as a deep understanding or colour and light applications in architectural spaces. Although relevant research has long been carried out within all these fields, knowledge is, however, fragmented and lacks coordination.
Research about light is largely concentrated on the development of technical applications, but also includes more basic research on light and human response to light [1, 2, 3]. Research about colour is mostly concerned with colour measurement and colour reproduction in different media, and only to some extent relevant to spatial design [4].
The academic research on colour and light is split among several disciplines and much of the research is being done within industrial companies. This division between different institutions and organisations has led to diverging research traditions and cognitive cultures. Thus, researchers and practitioners often have difficulty understanding and relating to one another's methods and results, although they work with similar questions. One important aspect of this is the absence of common and generally accepted concepts [5].
The poor epistemological foundations regarding colour, light and their spatial interaction have led to a number of theories that tried but failed to describe the experienced reality, thus giving poor guidance for practical applications. Consequently, there are different non-compatible worlds of knowledge.

3.2 Different scientific approaches

The field of colour and light includes a number of disciplines, ranging from technical to philosophical. Within them we can identify three major scientific approaches based on the theories and concepts of *psycho-physics*, *biology/ neurology* and *perception/cognition*.
The *psycho-physical approach* provides the theoretical basis for lighting technology and the instruments and algorithms of colour science. Its main foundations are experiments carried out in the early 20th century, since which time the understanding of the human visual system has advanced greatly. This has, however, not affected the basic colorimetric functions and concepts, which, although much debated, remain the same.
The *biological/neurological* approach is based on an understanding of the human visual sense, derived from investigations of neural and chemical signals in functioning systems as well as an analysis of their microscopic design. It has implications regarding such phenomena as colour vision and contrast perceptions, as well as non-visual effects like the production of hormones due to electromagnetic radiation.
The approach of *perception and cognition* starts from the fact that colour phenomena and significant perceptive pat-

terns are related to an inherent constituent order and/or to perceived logical structures in the world around [6]. Qualities like atmosphere and spatial experience are being investigated scientifically both within architectural research and by the light source industry, but, as the theories and methods are not physically based, this understanding is difficult to combine with results achieved with more technological methods [7, 8].

3.3 Problems concerning colour and light application

For practitioners in architectural design and town planning, the lack of a coherent field of knowledge means that efforts to gather and use relevant knowledge risk leading to random results. Consequently, colour and light are not used effectively to create positive experiences, but rather tend to give poorly integrated spaces creating disrupting experiences. The already mentioned epistemological problems have led to a praxis for lighting planning that is focused on the measurable intensity of light rather than on visual qualities like contrast and colour rendering, or non-visual effects like hormone production. Qualities like atmosphere and spatial experience are considered even less.

The established methods and measurements for describing the colour of light and the colour rendering qualities of a light source (*correlated colour temperature* and *Ra-index)* are not fully adequate even for the traditionally existing light sources, and have proven even more inadequate for new light sources like LED.

Window glass is marketed based on several qualities developed for reducing such factors as heat inflow and reflection, but its impact on interior light and colour is not systematically considered.

4. METHODOLOGY: SEMINARS AND SUBPROJECTS

The SYN-TES project gathers internationally acknowledged scientific and technical experts within a number of disciplines in colour and light, including architecture, psychology and medicine, as well as practitioners from leading companies working with lighting, colour and window glass. Each of the participants is actively involved in ongoing research or product development relevant to the problem complex, and through their co-operation in SYN-TES their theories, methods and results will be discussed with experts from other disciplines.

The main work has the form of seminars on various aspects of colour and light. The participants present front-line international research within their own disciplines and together identify coordination problems and suggest solutions.

Some of the identified problems are further investigated in sub-projects that include theoretical work, experiments and analyses of existing architectural spaces. The seminar group functions as an active reference group for subprojects. Two of these sub-projects are presented below.

5. SUBPROJECT PERCIFAL

5.1 Perceptive spatial analysis of colour and light

Colour and light are often discussed in terms that start from their physical qualities, which makes it difficult to understand their perceptual aspects. PERCIFAL aims at developing a methodology and a set of concepts for description and analysis of perceived colour and light in spatial situations. It starts from the method for visual evaluation presented by Professor Anders Liljefors [9] and is gradually adjusted and supplemented through the use in educational situations with students and professionals.

5.2 From pedagogic instrument to tool for specification of design outcome

The original method has purely educational purposes. One of PERCIFAL's aims is to further develop this pedagogical aspect. Another aim is to develop the method and its concepts into a tool for analysis of existing architectural spaces and for specification of aimed qualities in future design processes.

5.3 Preliminary set of criteria

The development process has so far resulted in the following visual criteria. For each of them the observer is instructed to look at the room as a whole and estimate the quality or its importance for the totality on a visual scale (Fig.1)

- Light level
- Light distribution on eye level
- Light distribution between different heights of the room
- Contrasts through cast shadows
- Contrasts through cast light effects from light sources or windows
- Reflexes and gleam from shiny surfaces
- Glare from light sources, windows or reflexes
- Light colour from the light sources in the room
- Surface colours, general impression of the whole room (warm - cold and unified – diverted)
- Contrasts between surface colours
- Possibility to understand forms in the room
- Possibility to understand surface textures
- Colour of human skin (very natural – very unnatural)
- Possibility to see the face expression of people in the room
- Possibility to read a given text in small size

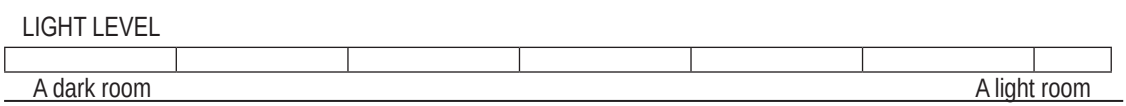

Fig.1 Example from estimation form

5.4 Preliminary result discussion

So far the method has been tested by four groups and results have not been fully analysed. We have, however, already found an alarming discrepancy between psycho-physically based criteria (e.g. lux recommendations) and visual estimations.

One example is the famous rotunda in Stockholm City Library, designed by Gunnar Asplund in 1928 (Fig. 2). A group of design students unanimously estimated the room as light or very light, and had no difficulty reading a text of 8p

Times New Roman. The lux values in the room varied between 100 and 150. Such lux levels are recommended only for spaces where only limited sight is required, such as garages or garbage rooms. For localities like libraries the recommended lux level is 500 lux [10].
This suggests that lux level is not a very reliable way of telling the perceived and functional lightness of a space. One reason for this is most likely the adaptation of our visual sense, which is totally dependent on the situation and cannot be considered in recommendations meant for general application.

6. SUBPROJECT OPTIMA

OPTIMA investigates how colour and lighting design affect spatial experience, functionality and energy consumption. The aim is to understand how artificial light, daylight and the shape and colours of the room interact in achieving different qualities, and the possible conflicts between these qualities.
Criteria for different aspects of ”good” lighting, including a maximum of energy consumption, have been formulated by the SYN-TES seminar group. A full scale experiment room is given a few alternative designs, starting from these criteria (Fig. 3).
The rooms will be evaluated by observers. Lux levels and energy consumption will be measured.
The observations will take place during the autumn of 2010, and at the conference we can present some preliminary results.

Fig. 2
The rotunda in Asplund’s City Library

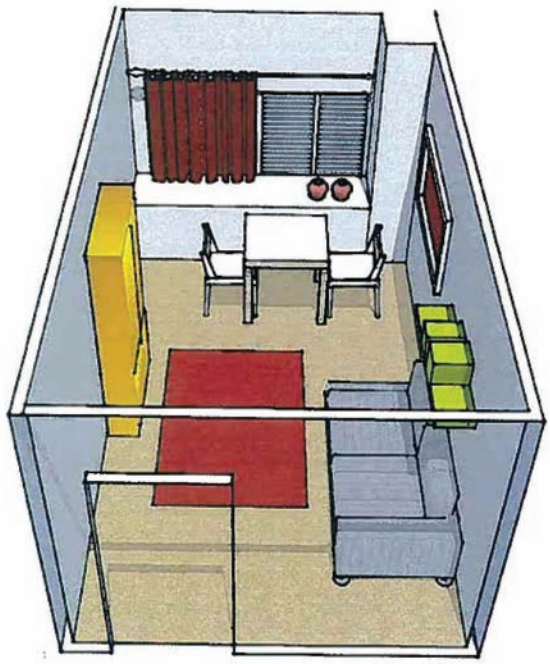

Fig.3
Experiment room with one of alternative colour designs

7. CONCLUSION

The concepts used in public discussion about colour and light – and also among professionals – are essentially derived from natural sciences and their conception of the world; concepts describing colour and light qualities are based upon physics or psychophysics. To a lesser extent – and only in limited fields – concepts are used that originate from *perception* of colour and light. There is, however, a need for reflection on how relevant the concepts based on natural science are to human experience of the world.

In a human context it is necessary to regard colour and light as related and functional parts of a comprehensive, coordinated and dynamic processes that influence our experience of the world as a whole. This includes both physical and mental aspects.

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